OROVILLE FERC RELICENSING
(PROJECT NO. 2100)

INTERIM REPORT
SP-F3.2 TASK 2
SP-F21 TASK 1

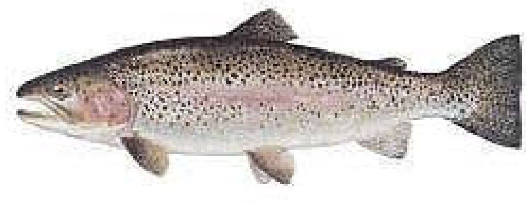
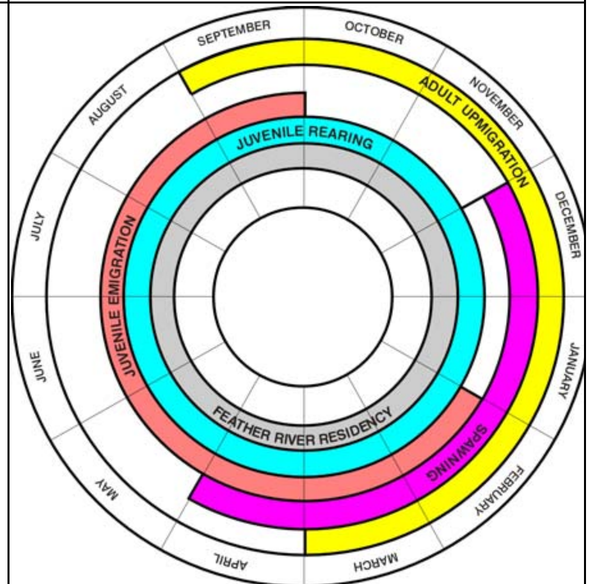
APPENDIX A
MATRIX OF LIFE HISTORY AND HABITAT REQUIREMENTS FOR FEATHER RIVER FISH SPECIES

LITERATURE REVIEW OF LIFE HISTORY AND HABITAT REQUIREMENTS FOR FEATHER RIVER FISH SPECIES

STEELHEAD

JANUARY 2003

Element	Element Descriptor	General	Feather River Specific
General			
common name (s)	English name (usually used by fishers and laypeople).	Steelhead (anadromous populations), coastal rainbow trout (migratory or anadromous populations), rainbow trout (non-anadromous populations), redband trout (native, mostly resident forms in interior basins) (Moyle 2002).	Steelhead (migratory or anadromous populations), rainbow trout (non-anadromous populations).
scientific name (s)	Latin name (referenced in scientific publications).	*Oncorhynchus mykiss*	
taxonomy (family)	Common name of the family to which they belong. Also indicate scientific family name.	Salmon, trout, char – *Salmonidae* The flexibility in steelhead life history patterns engendered many local populations to be distinct and awarded taxonomic recognitions. Major controversies arose regarding subspecies designations for various evolutionary groups in non-anadromous populations (rainbow trout) and designations for ESUs in anadromous populations (steelhead) and their resident derivatives (Moyle 2002). Two ecotypes of steelhead (McEwan 2001): ▪ Stream-maturing steelhead (summer-run), which enter freshwater with immature gonads and must spend several months in the stream. ▪ Ocean-maturing steelhead (winter-run), which mature in the ocean and hold in freshwater for a relatively short time.	Rivers of the Central valley contain only winter-run steelhead (Moyle 2002) but summer-run steelhead may have been more common before the dam construction that they are today (McEwan 2001).

Element	Element Descriptor	General	Feather River Specific
depiction	Illustration, drawing or photograph.		
range	Broad geographic distribution, specifying California distribution, as available.	Rainbow trout are the most abundant and widespread native salmonid in western North America, and are likely the most widely distributed fish in California. Steelhead are originally native to Pacific coast streams from the Kuskokwim River in Alaska to the streams of Baja California. In Asia, rainbow trout are native mainly to the north Pacific coast south of the Kamchatka Peninsula. In salt water, steelhead are found throughout the North Pacific ocean (Moyle 2002).	
native or introduced	If introduced, indicate timing, location, and methods.	Native.	Native.

Element	Element Descriptor	General	Feather River Specific
ESA listing status	Following the categories according to California Code of Regulations and the Federal Register, indicate whether: SE = State-listed Endangered; ST =State-listed Threatened; FE = Federally listed Endangered; FT = Federally-listed Threatened; SCE = State Candidate (Endangered); SCT = State candidate (Threatened); FPE = Federally proposed (Endangered); FPT = Federally proposed (Threatened); FPD = Federally proposed (Delisting); the date of listing; or N = not listed.	Central Valley steelhead were federally listed as Threatened on March 19, 1998 (NMFS 1998). The Sacramento and San Joaquin Rivers and their tributaries were designated as Critical Habitat on March 17, 2000 (California Department of Fish and Game 2002). Non-anadromous rainbow trout are excluded from the listing.	
species status	If native, whether: Extinct/extirpated; Threatened or Endangered; Special concern; Watch list; Stable or increasing. If introduced, whether: Extirpated (failed introduction); highly localized; Localized; Widespread and stable; Widespread and expanding.	Central Valley steelhead are included in class IB (Threatened or Endangered) (Moyle 2002). Apparent wild steelhead are found in the Sacramento system (e.g., substantial, but not quantified, population of wild steelhead in lower Yuba River).	Steelhead population supported by a hatchery program.
economic or recreational value	Indicate whether target species sought for food or trophy. Whether desirable by recreational fishers, commercial fishers, or both.	Prized recreational species. Regulated recreational fishery on hatchery-produced steelhead; regulations vary by stream (CDFG 2002; McEwan et al. 1996). In the Sacramento and Klamath river systems, steelhead account for over $20 million annually (16% of the total salmonid commercial and sport fish revenues for these systems) (McEwan et al. 1996).	Recreational fishery.

Element	Element Descriptor	General	Feather River Specific
warmwater or coldwater	Warmwater if suitable temperature range is similar to basses; coldwater if suitable temperature range is similar to salmonids.	Coldwater.	
pelagic or littoral	Environment: Pelagic - living far from shore; Littoral - living near the shore.	Pelagic ocean residence. Nearshore orientation as fry; moving into swifter, deeper water as larger juveniles in freshwater.	
bottom or water column distribution	Environment: bottom (benthic) or along water column.	Both free-swimming and positively reotactic at various freshwater lifecycles.	
lentic or lotic	Environment: Lentic - pertaining to stagnant water, or lake-like; Lotic - moving water, or river-like.	Lotic.	
Adults			
life span	Approximate maximum age obtained.	Steelhead may live for up to 9 years (Moyle 2002). Rainbow trout rarely reach 5 years old, but may reach 6 to 7 years (Moyle 2002).	
adult length	Indicate: Length at which they first reproduce; average length and maximum length the fish can attain.	Sacramento River basin steelhead immigrants range in size from 12–18 inches (304.8–457.2 mm) FL for adults returning after 1 year in the ocean, to 18–23 inches (457.2–584.2 mm) FL for adults returning after 2 years in the ocean (S.P. Cramer & Associates 1995). Rainbow trout reach lengths of 11.8 - 13.8 inches (30-35 cm) FL in the McCloud River, at an age of 6-7 years (Moyle 2002). The growth rate of steelhead is highly variable. In relatively large streams, steelhead reach 3.9–4.7 inches (100–120 mm) FL at year 1, and reach 6.3–6.7 inches (160–170 mm) FL at year 2. In relatively small streams with low summer flows, steelhead reach 1.9–3.5 inches (50–90 mm) FL at year 1, and 3.9–6.3 inches (100–160 mm) at FL year 2 (Moyle 2002).	

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		Steelhead typically reach maturity at 3–4 years of age. Age at maturity depends on the combination of the number of years in freshwater (1–-3 yrs) and the number of years in the ocean (1–4 yrs). In Waddel Creek, most fish sampled were of the following types: 2:1 (30%), 2:2 (27%), 3:1 (11%), and 1:2 (8%) (expressed as years in freshwater:years in the ocean) (Moyle 2002). Approximately 57% of Sacramento River steelhead spawn after 1 year in the ocean, and approximately 43% spawn after 2 years in the ocean (Busby P.J. et al. 1996). Age at spawning can be estimated by adding the number of years spent in freshwater to the number of years spent in the ocean. Thus, the age at first spawning is typically 2-4 years.	
adult weight	Indicate: Weight at which they first reproduce; average weight and maximum weight the fish can attain.	The reported largest steelhead caught in California, weighing 27.3 pounds (12.4 kg), was caught in the Smith River. The reported largest steelhead on record was caught in Alaska, and weighed 42.1 pounds (19.1 kg) (Moyle 2002).	The largest non-steelhead rainbow trout reported in California, weighing 21.2 pounds (9.6 kg), was caught in the Feather River (Moyle 2002).
physical morphology	General shape of the fish: elongated, fusiform, laterally compressed, etc.	Fusiform (streamlined).	
coloration	Indicate color, and color changes, if any, during reproduction phase.	Broad red lateral band apparent during spawning.	
other physical adult descriptors	Unique physical features for easy identification.		
adult food base	Indicate primary diet components.	Stream-dwelling rainbow trout feed on terrestrial and aquatic insects, insect larvae, amphipods, snails, and small fish. During the winter, they feed primarily on bottom-dwelling invertebrates (Moyle 2002). Diet of adult steelhead in the ocean is comprised of fish, squid, and crustaceans in surface waters (Moyle 2002).	

Element	Element Descriptor	General	Feather River Specific
adult feeding habits	Indicate whether plankton eater, algae eater, bottom feeder, piscivorous, active hunter, ambush predator, filter feeder. Night, day, dusk or dawn feeder.	Adult steelhead in streams feed opportunistically, but individuals may have specialized diets (i.e., feeding primarily on one organism) (Moyle 2002). Adult rainbow trout feed during the day or at night, but peak feeding typically occurs at dawn and dusk (Moyle 2002). Actively feed in freshwater.	
adult in-ocean residence time	For anadromous species, age when they migrate to the ocean and duration spent in the ocean before returning to freshwater to spawn.	Steelhead smolts migrate out to sea at 1-3 years of age, and stay there for 1-2 years (Moyle 2002). Adults spend 1-2 years in the ocean; the proportion of "2-salt" (i.e., 2 years in ocean) individuals, relative to "1-salt" individuals, increases with a northward movement in latitude (S.P. Cramer & Associates 1995).	
adult habitat characteristics in-ocean	For anadromous species, description of the ocean habitat utilized: whether along major current systems, gyres, pelagic (beyond continental shelves) and neritic (above continental shelves) zones, etc.	Adult steelhead habitat utilization in the ocean is poorly known, but it is likely that most California steelhead do not move far from the California coast (Moyle 2002).	
Adult upstream migration (immigration)			
range of adult upstream migration timing	Time of year adults migrate upstream. If applicable, indicate for various runs.	Winter-run Central Valley steelhead begin entering freshwater in August (Moyle 2002). Central Valley steelhead adult migration ranges from July through May (McEwan 2001). Central Valley steelhead adult migration occurs from August through April (Busby P.J. et al. 1996).	Based on 1953-1959 data from immediately upstream of the confluence of the Sacramento River and Feather River, steelhead immigrate into the Feather River from July to March (McEwan 2001). Feather River steelhead begin entry into freshwater from September through June (Busby P.J. et al. 1996).
peak adult upstream migration timing	Time of year most adults migrate upstream. If applicable, indicate for various runs.	Peak Central Valley steelhead immigration occurs from late September through October (Moyle 2002). Peak Central Valley steelhead immigration occurs from September through March. Adult steelhead tend to migrate during high-flow periods (McEwan	Upstream migration of adult steelhead to the Feather River confluence with the Sacramento River peaks in October and November (S.P. Cramer & Associates 1995).

Element	Element Descriptor	General	Feather River Specific
		2001).	
adult upstream migration water temperature tolerance	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	Water temperatures lethal to adult steelhead have been reported at 70°F (21.1°C) (Rich 2000). For adult trout, especially adult steelhead, lethal temperatures are approximately 73.4°F–75.2°F (23°C–24°C) (Moyle 2002).	
adult upstream migration water temperature preference	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental.	Based on northern stocks, the reported optimal temperature range for migrating adult steelhead is 46°F–52°F (7.8°C–11.1°C) (DWR et al. 2000).	
Adult holding (freshwater residence)			
water temperature tolerance for holding adults	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	For adult trout, especially adult steelhead, lethal temperatures are approximately 73.4°F–75.2°F (23°C–24°C) (Moyle 2002). Summer-run steelhead can survive exposure to water temperatures from 77°F to 80.6°F (25°C–27°C) for short periods (Moyle 2002). Rainbow trout are found in streams in which daytime water temperatures range from 32°F (0°C) in the winter to 80.6°F (27°C) in the summer. Water temperatures <39.2°F (<4°C) and >73.4°F (>23°C) are lethal to unacclimated fish (Moyle 2002).	
water temperature preference for holding adults	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental.	Reported optimal temperatures for growth of rainbow trout range from approximately 59°F to 64.4°F (15°C–18°C). In summer, when water temperatures fluctuate, reported optimal water temperatures are from approximately 3°F–5°F (2°C–3°C), lower than in streams with more constant conditions (Moyle 2002). Summer-run steelhead prefer cold pools in the range of 50°F–59°F (10°C–15°C) during summer months (Moyle 2002).	

Element	Element Descriptor	General	Feather River Specific
water depth range for holding adults	Reported range of observed (minimum and maximum) water depth utilization.	The minimum depth requirement for passage of adults is reported to be 7 inches (177.8 mm) (DWR et al. 2000).	
water depth preference for holding adults	Reported range of most frequently observed water depth utilization.	Summer-run steelhead prefer holding in deep pools [9.8 feet (3 m) or more] (Moyle 2002).	
substrate preference for holding adults	If bottom dwellers, indicate substrate: mud, sand, gravel, boulders, aquatic plant beds, etc. If gravel, indicate range or average size of gravel.		
water velocity range for holding adults	Reported range of observed (minimum and maximum) water velocity utilization.	Adult steelhead are reported to withstand maximum water velocities of 10–13 ft/sec (3.0–3.10 m/sec) (DWR et al. 2000).	
water velocity preference for holding adults	Reported range of most frequently observed water velocity utilization.		
other habitat characteristics for holding adults	General description of habitat (e.g. turbid or clear waters, lentic or lotic, presence of aquatic plant beds, debris, cover, etc.).		
timing range for adult holding	Time of year (earliest-latest) and duration of stay from upstream migration to spawning.	Central Valley winter-run steelhead mature in the ocean and arrive on the spawning grounds nearly ready to spawn. Summer steelhead, or stream-maturing steelhead, enter freshwater with immature gonads and typically spend several months in freshwater before spawning (DWR et al. 2000).	Because Feather River steelhead are believed to be ocean-maturing (winter-run), they likely exhibit a relatively short holding duration.
timing peak for adult holding	Time of year when maximum number of adults are present before spawning.		
Spawning			
fecundity	Average or range in the number of eggs females lay in a spawning season.	Fecundity is highly variable, ranging from 200 to 12,000 eggs per female. Steelhead contain approximately 2,000 eggs per pound (900 eggs per kg) of body weight. Rainbow trout under 11.8 inches (30 cm) TL contain fewer than 1,000 eggs	

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		(Moyle 2002). In the American River, mature female steelhead contain from 1,500 to 4,500 eggs, with an average of approximately 3,500 eggs/female. In the Sacramento River, the average is approximately 1,500 eggs/female (U.S. Fish and Wildlife Service 1995).	
nest construction	Location and general description of nest -- substrates, aquatic plants, excavations, crevices, habitat types, etc.	Construct nests (redds) in coarse gravels with relatively swift water.	
nest size	Size and average dimensions of the nest.	Steelhead redds can contain up to 1,000 eggs, and 6 to 7 redds are required to complete spawning. The average redd size for Sacramento River basin steelhead is 56 ft^2 (5.2 m^2), which is smaller than the average redd size in most California streams (U.S. Fish and Wildlife Service 1995). Based on field observations of 54 redds in the Clearwater and Salmon river watersheds in Idaho, the average redd size was 6.5 yd^2 (5.4 m^2), with a range of 2.5–13.4 yd^2 (2.09–11.2 m^2) (Orcutt et al. 1968).	
spawning process	Indicate whether nest builder, broadcast spawner, or other.	Nest builders. Males remain 2 weeks longer than females after spawning, and surviving spawners return to sea between April and June (U.S. Fish and Wildlife Service 1995).	
spawning substrate size/characteristics	Range of substrates used during spawning (e.g. mud, sand, gravel, boulders, beds of aquatic plants). Indicate presence of plant/wood debris, crevices at spawning sites. If gravel, indicate range of average size.	Steelhead spawning occurs over coarse gravel 0.5–5.1 inches (1–13 cm) in diameter in the tail of a pool or in a riffle (Moyle 2002). Approximately 70% of spawning gravels sampled in 68 redds in the Clearwater and Salmon river watersheds in Idaho were between 0.5 to 4 inches (1–10.6 cm) in diameter (Orcutt et al. 1968).	

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preferred spawning substrate	Indicate preferred spawning substrate (e.g. mud, sand, gravel, boulders, plant bed, etc).	The preferred gravel particle size for steelhead spawning ranges from 0.25 to 3.0 inches (0.6–7.6 cm) in diameter, with less than 5% sand and silt by weight for higher permeability (U.S. Fish and Wildlife Service 1995).	
water temperature tolerance for spawning	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	The following temperature ranges and stress levels are reported for steelhead: ▪ Chronic low stress: 52.1°F–57.5°F (11.2°C–14.7°C); ▪ Chronic medium stress: 57.6°F–61.0°F (14.2°C–16.1°C); and, ▪ Chronic high stress: Greater than 61.0°F (16.1°C) (U.S. Fish and Wildlife Service 1995). Water temperatures ranged from 36°F–47°F (2.2°C–8.3°C) during peak spawning (mid April to mid May), in the Clearwater and Salmon river watersheds in Idaho (Orcutt et al. 1968).	
water temperature preference for spawning	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation.	The reported optimum temperature range for steelhead spawning is 46.0°F–52.0°F (7.8°C–11.1°C) (U.S. Fish and Wildlife Service 1995). Based on a literature review, the reported preferred temperature range for spawning Central Valley steelhead is 39°F–52°F (3.9°C–11.1°C) (IEP 1998).	
water velocity range for spawning	Minimum and maximum speed of water current the spawning fish can tolerate.	Water velocities over steelhead redds typically range from 0.65–5.1 ft/sec (20–155 cm/sec) (Moyle 2002). The reported water velocity range for steelhead spawning is 0.5–3.6 ft/sec (15.2–109 cm/sec) (U.S. Fish and Wildlife Service 1995).	
water velocity preference for spawning	Preferred water current (flow velocity) during spawning.	Reported preferred water velocity for steelhead spawning is 1.5 ft/sec (45.7 cm/sec) to 2.0 ft/sec (60.9 cm/sec) (U.S. Fish and Wildlife Service 1995).	
water depth range for spawning	Reported range of observed (minimum and maximum) water depth utilization.	Typically, steelhead redds are constructed at a depth of 0.3–4.9 feet (10–150 cm) (Moyle 2002).	

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		Steelhead redds are constructed at depths of 5–28 inches (12.7–71.1 cm) (U.S. Fish and Wildlife Service 1995). In the Clearwater and Salmon river watersheds in Idaho, the shallowest water recorded over a redd was 0.7 ft (0.2 m); while maximum depth was not measured in this study, redds *"were observed in depths exceeding 5 ft (1.5 m)"* (Orcutt et al. 1968).	
water depth preference for spawning	Reported range of most frequently observed water depth utilization.	The average water depth for spawning is 14 inches (35.6 cm) (U.S. Fish and Wildlife Service 1995).	
range for spawning timing	Earliest and latest time of season or year in which spawning occurs.	Central Valley winter-run steelhead spawn from December through March (Moyle 2002). Central Valley winter-run steelhead spawning can occur from October through June (McEwan 2001).	Central Valley steelhead in the Feather River spawn from November through June (Busby P.J. et al. 1996).
peak spawning timing	Time of year most fish start to spawn.	Peak spawning for Central Valley winter-run steelhead occurs from January through February (Moyle 2002). The peak spawning range for Central Valley winter-run steelhead occurs from December through April (McEwan 2001). Peak spawning for California steelhead occurs from December through April (IEP 1998).	Peak spawning for Central Valley steelhead in the Feather River occurs from January through February (Busby P.J. et al. 1996).
spawning frequency (iteroparous/semelparous)	Semelparous - producing all offspring at one time, such as in most salmon. Usually these fish die after reproduction. Iteroparous - producing offspring in successive, e.g., annual or seasonal batches, as is the case in most fishes.	Iteroparous. Both rainbow trout and steelhead spawn annually, but can skip a year between spawns. Steelhead can spawn up to four times, but mortality rates increase with subsequent spawns (50–75%) (Moyle 2002). Steelhead in California and Oregon are primarily 2-time spawners. Steelhead in these regions rarely spawn three times. Iteroparous steelhead are predominantly female (Busby P.J. et al. 1996).	
Incubation/early development			
egg characteristics	Shape, size, color, in clusters or individuals, stickiness, and other physical attributes.	Steelhead eggs are pink to orange in color, generally spherical or slightly irregular, ranging in size from 0.12–0.24 inches (3–6.2 mm). The eggs are deposited in loose clusters or piles, and	

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		have been reported to range from adhesive during the water hardening process to not adhesive. Steelhead eggs are demersal (Wang 1986).	
water temperature tolerance for incubation	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	Total mortality is believed to occur at water temperatures of approximately 63°F or higher.	
water temperature preference for incubation	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation.	At temperatures of 50°F–59°F (10°C–15°C), eggs will hatch in 3 to 4 weeks (Moyle 2002). Based on literature review, the range of 48°F to 52°F (8.9°C–11.1°C) is preferred for steelhead egg incubation and emergence (IEP 1998).	
time required for incubation	Time duration from fertilization to hatching. Note: Indicate at which temperature range. Incubation time is temperature-dependent.	At temperatures of 50°F–59°F (10°C–15°C), eggs will hatch in 3 to 4 weeks (Moyle 2002). Steelhead eggs will hatch in 19 days [at 60°F (15.6°C)], and in 80 days [at 40°F (4.4°C)] (U.S. Fish and Wildlife Service 1995). Steelhead eggs will hatch in approximately 4 weeks at temperatures of 48°F–52°F (8.9°C–11.1°C) (DWR et al. 2000). Hatchery steelhead will hatch in 30 days at 51°F (10.6°C) (McEwan et al. 1996).	
size of newly hatched larvae	Average size of newly hatched larvae.	At hatching, steelhead larval steelhead are approximately 0.55 to 0.61 inches (14.0-15.5 mm) TL (Wang 1986).	
time newly hatched larvae remain in gravel	Time of year of hatching, and duration between hatching and emergence from gravel.	Newly hatched steelhead remain in gravel for 2 to 3 weeks (Moyle 2002). Fry emerge from gravel 2 to 8 weeks after hatching (U.S. Fish and Wildlife Service 1995). After hatching, the yolk-sac fry or alevins remain in gravel for 4 to 6 weeks (DWR et al. 2000).	
other characteristics of larvae	Alevin -- early life history phase just after hatching (larva) when yolk-sac still present.		

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timing range for emergence	Time of year (earliest-latest) hatchlings (larvae and alevins) leave or emerge from the nesting/hatching (gravel) sites.	Emergence ranges from January through April, based on 3 weeks of incubation and 3 weeks post-hatch residence time in gravel (i.e., 6 weeks added to the spawning timing range) (Moyle 2002). Central Valley winter-run steelhead incubation and emergence occurs from December through August (McEwan 2001).	
timing peak for emergence	Time of year most hatchlings emerge.	Peak emergence ranges from mid-February through March, based on 3 weeks of incubation and 3 weeks post-hatch residence time in gravel (i.e., 6 weeks added to the peak spawning range) (Moyle 2002). Central Valley winter run steelhead incubation and emergence peak: January–June (McEwan 2001).	
size at emergence from gravel	Average size of hatchlings at time of emergence.		
Juvenile rearing			
general rearing habitat and strategies	General description of freshwater environment and rearing behavior.	Regardless of life history strategy, for the first year or two of life rainbow trout and steelhead are found in cool, clear, fast-flowing permanent streams and rivers where riffles predominate over pools, there is ample cover from riparian vegetation or undercut banks, and invertebrate life is diverse and abundant (Moyle 2002). Following emergence, steelhead fry usually live in small schools in shallow waters along stream banks. As the steelhead grow, the schools break up and they establish individual feeding territories. Most steelhead live in riffles during year 1. Larger steelhead live in deeper, faster runs or pools. Their appearance and life are similar to that of non-anadromous resident rainbow trout. In comparison to Chinook salmon, which emigrate within a few months after emergence, steelhead rear to a relatively larger size. Consequently, juvenile steelhead are more dependent on larger and more abundant food resources than Chinook	

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		salmon and utilize deeper and faster runs and pools as they grow to larger sizes before emigration (U.S. Fish and Wildlife Service 1995).	
water temperature tolerance for juvenile rearing	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	The following temperatures are reported for fry and juvenile rearing: ▪ chronic low stress: 60.1°F–68.0°F (15.6°C–20°C); ▪ medium stress: 68.1°F–72.5°F (20.1°C–22.5°C); and, ▪ high stress: greater than 72.5°F (>22.5°C) (U.S. Fish and Wildlife Service 1995). Mean critical thermal maxima under laboratory conditions for Nimbus hatchery strain juvenile steelhead ranged from 82°F–85.3°F (27.8 °C–29.6°C) across different temperature and ration treatments. Higher rearing/acclimation temperatures [i.e., 59°F (15°C) and 66.2°F (19°C) vs. 51.8°F (11°C)] resulted in significantly higher critical thermal maxima. Ration did not result in critical thermal maxima effects, except within the 59°F (15°C) acclimation treatment (Cech et al. 1999). Rainbow trout are found where daytime water temperatures range from 32°F (0°C) in the winter to 80.6°F (27°C) in the summer. Water temperatures less than 39.2°F (<4°C) and greater than 73.4°F (>23°C) are lethal for unacclimated fish (Moyle 2002).	Mean critical thermal maxima[1] for wild Feather River juveniles ranged from 87.1°F to 87.8°F (30.6°C to 31.0°C) in fasted and fed trial groups, respectively, under experimental conditions. Mean critical thermal maxima for hatchery-produced Feather River juvenile steelhead ranged from 84.9°F to 85.6°F (29.4°C to 29.8°C) across a range of ration levels under laboratory conditions. The difference between experimental critical thermal maxima for wild and hatchery produced steelhead is statistically significant, suggesting that wild fish in the Feather River have a higher thermal tolerance than do hatchery-reared fish (Myrick et al. 2000).
water temperature preference for juvenile rearing	Range of suitable, preferred, or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation.	The reported optimum temperature range for fry and juvenile rearing is 55°F–60°F (12.8°C–15.5°C) (U.S. Fish and Wildlife Service 1995). In laboratory trials with Nimbus Hatchery strain juvenile steelhead, preferred water temperatures	Wild and hatchery-produced juveniles from the Feather River preferred water temperatures between 62.6°F–68°F (17°C–20°C) under laboratory conditions (Myrick et al. 2000).

[1] Young and Cech (1996) describe the critical thermal maxima as "*the ecological lethal index because animals in nature may encounter such temperatures as acute fluctuations above their tolerance limits…*" (Hutchison 1976).

Element	Element Descriptor	General	Feather River Specific
		ranged from 62.6°F–68°F (17°C–20°C), regardless of ration level or rearing/acclimation temperature (Cech et al. 1999). The reported preferred range for newly emerged fry is 45°F–60°F (7.2°C–15.5°C) (DWR et al. 2000). Based on literature review, the reported preferred water temperature range for fry and juvenile rearing is between 45°F–60°F (7.2°C–15.5°C) (IEP 1998).	
water velocity ranges for rearing juveniles	Reported range of observed (minimum and maximum) water velocity utilization.	Steelhead fry utilize water velocities of 0.3-1.0 ft/sec (0.09–0.3 m/sec) (U.S. Fish and Wildlife Service 1995). Steelhead juveniles utilizes water velocities of 0.3-1.5 ft/sec (0.09–0.46 m/sec) (U.S. Fish and Wildlife Service 1995). In laboratory trials with Nimbus Hatchery strain juvenile steelhead, critical swimming velocities ranged from 1.7–2.2 ft/sec (0.51 m/sec to 0.67 m/sec) across varied temperature and ration treatments (Cech et al. 1999).	YOY steelhead in the Feather River were observed from February through August. In February, all YOY observed were found at velocities of 0-0.50 ft/sec (0–0.15 m/sec); in April and June, YOY were observed in increasingly swifter waters, ranging from 0-0.50 ft/sec (0–0.15 m/sec) to greater than 3.0 ft/sec; in July, the greatest proportion of YOY steelhead were observed in waters greater than 3.0 ft/sec (0.91 m/sec); in August, the distribution of YOY steelhead approached normal (slightly skewed), with the greatest proportion of fish using 1.51–2.0 ft/sec (0.46–0.61 m/sec) waters, and greater proportions of fish in velocities of 2.01–3.0 ft/sec (0.61–0.91 m/sec) than 0–1.5 ft/sec (0–0.46 m/sec) (DWR 2003).
water velocities preferred by rearing juveniles	Reported range of most frequently observed water velocity utilization.	Reported optimal water velocities for steelhead fry (<2 inches or <50 mm in size) are 0.03–0.82 ft/sec (1-25 cm/sec). Reported optimal water velocities for steelhead juveniles 2–3.9 inches (50-100 mm) in length are 0.33–0.98 ft/sec (10-30 cm/sec) (Moyle 2002). The reported optimal water velocity for steelhead fry is 0.6 ft/sec (.18 m/sec) (U.S. Fish and Wildlife Service 1995). The reported optimal water velocity for steelhead juveniles is 0.9 ft/sec (.27 m/sec) (U.S. Fish and	

Element	Element Descriptor	General	Feather River Specific
		Wildlife Service 1995).	
water depth range for juvenile rearing	Reported range of observed (minimum and maximum) water depth utilization.	Steelhead fry utilize water approximately 2–32 inches (.05 m–0.8 m) in depth (McEwan 2001). Steelhead juveniles utilize water approximately 2–60 inches (0.5 m–1.5 m) in depth (McEwan 2001).	From February through August, YOY steelhead in the Feather River were observed at increasingly greater water depths; initially (i.e., in February) 100% observed were found between 0–9.4 inches (0–0.24 m); in March, over 60% of YOY steelhead remained at depths of 0–9.4 inches (0–0.24 m), and approximately 30% of fish utilized depths between 9.8 inches (0.25 m) and 19.3 inches (0.49 m) [with a small proportion between 9.7–19.1 inches (0.50–0.74 m)]; in April, the general distribution observed in March remained, with the addition of a small proportion of fish utilizing depths greater than 39.4 inches (1 m); in May, more YOY were observed in depths between 9.8–19.3 inches (0.25–0.49 m) and 9.7–19.1 inches (0.50–0.74 m), with smaller proportions observed at 0–9.4 inches (0–0.24 m) (<40%); in June, the largest proportion of fish observed were observed between 9.8–19.3 inches (0.25–0.49 m); in July, YOY steelhead were observed primarily in the 0–9.4 inches (0–0.24 m), 9.8–19.3 inches (0.25-0.49 m), and 9.7–19.1 inches (0.50-0.74 m) depth ranges, in proportions of slightly greater than 40%, slightly less than 40%, and approximately 30%, respectively [with few observations in the 29.5–38.10 inches (0.75–0.99 m range) (DWR 2003)].
water depth preference for juvenile rearing	Reported range of most frequently observed water depth utilization.	Steelhead fry typically use water approximately 8 inches (0.20 m) in depth (McEwan 2001). Juvenile steelhead typically use water approximately 15 inches (0.38 m) in depth (McEwan 2001).	

Element	Element Descriptor	General	Feather River Specific
cover preferences for rearing juveniles	Type of cover for protection from predators used by rearing juveniles (e.g. crevices, submerged aquatic vegetation, overhanging vegetation, substrate cover, undercover bank, small woody debris, large woody debris).	Steelhead fry will remain close to stream edges. Steelhead juveniles utilize rocks and other cover, and larger juvenile steelhead also utilize pockets behind rocks, runs or pools (Moyle 2002). Juvenile steelhead utilize relatively shallow depths and fast water velocities, which are less suitable to pikeminnows to avoid predation [i.e., in the Eel River, steelhead utilized depths of 27.6–15.4 inches (70–39 cm)], and water velocities of 0.46–1.4 ft/sec (14–44 cm/sec)] (Moyle 2002).	YOY steelhead in the Feather River were observed using small woody debris, large woody debris, overhead objects, aquatic vegetation, and undercut banks for cover; large woody debris and undercut bank were used the least frequently among cover types, and YOY were observed using no apparent cover with a frequency of use approximately equal to that of small woody debris and aquatic vegetation (DWR 2003). From February through August, YOY steelhead in the Feather River were observed at increasing distances from the channel edge, with the peak distance from edge occurring in July [from approximately 11.8 inches (0.3 m) in February to approximately 70.9 inches (1.8 m) in July] (DWR 2003).
food base of juveniles	Indicate primary diet components. Also indicate the diet changes, if any, as growth occurs.	Rearing juveniles feed on a variety of aquatic and terrestrial insects and other small invertebrates (U.S. Fish and Wildlife Service 1995). The gut content of juvenile steelhead seined from the lower American River was comprised primarily of chironomids, corixids, baetid mayflies, and hydropsychid caddisflies (Merz 1994). In the lower American River, where fluctuating flows from dam releases tend to limit the diversity of benthic organisms, steelhead feed largely on mayfly adults and larvae of chironomid midges (Moyle 2002). Anadromous steelhead leaving their home streams feed on estuarine invertebrates and marine krill (Moyle 2002).	
feeding habits of rearing juveniles	Indicate whether plankton eater, algae eater, bottom feeder, piscivorous, active hunter, ambush predator, filter feeder. Night, day, dusk or dawn feeder. Also indicate	Based on sampling of the lower American River, juvenile steelhead feed throughout the day, with peak feeding occurring at dawn (Merz 1994).	

Element	Element Descriptor	General	Feather River Specific
	change of feeding habits growth occurs.		
predation of juveniles	Indicate which species prey on juveniles.	Avian predators of steelhead include kingfishers, mergansers, and herons. Large trout and pikeminnow also are predators of juvenile steelhead (Moyle 2002). Predators of steelhead include striped bass, pikeminnow, pinnipeds (adults and juveniles), and seabirds (S.P. Cramer & Associates 1995). It has been observed that steelhead fry can become prey of older steelhead (U.S. Fish and Wildlife Service 1995).	
timing range for juvenile rearing	Range of time of year (months) during which rearing occurs.	Central Valley steelhead rear year-round (McEwan 2001).	
timing peak for juvenile rearing	Time of year (months) during which most rearing occurs.	Central Valley steelhead rear year-round (McEwan 2001).	
Juvenile emigration			
time spent in fresh water prior to emigrating	Duration (in years and/or months) from emergence to emigration to the ocean.	Juvenile steelhead can rear for nearly one year or longer before emigrating (U.S. Fish and Wildlife Service 1995). Most naturally produced Central Valley steelhead rear for two years prior to emigrating (McEwan 2001). Juvenile steelhead will rear for 1–2 years, longer than the rearing period for Chinook salmon (U.S. Fish and Wildlife Service 1995). Juvenile Central Valley steelhead will remain in freshwater for 1–3 years (DWR et al. 2000).	

Element	Element Descriptor	General	Feather River Specific
		For ocean-maturing steelhead in the Sacramento River, 32% of juveniles emigrate after 1 year in freshwater, and 69% of juveniles emigrate after 2 years in freshwater (Busby P.J. et al. 1996).	
water temperature tolerances during emigration	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	The following temperatures are reported for juvenile emigration: ▪ chronic low stress: 52.4°F–59.3°F (11.3°C–15.2°C) ▪ medium stress: 59.4°F–63.2°F (15.2°C–17.3°C) ▪ high stress: >63.2°F (17.3°C) (U.S. Fish and Wildlife Service 1995).	
water temperature preferences during emigration	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation.	The reported optimal water temperature range for juvenile emigration is 44.4°F–52.3°F (6.9°C–11.3°C) (U.S. Fish and Wildlife Service 1995). For northern populations of steelhead, water temperatures under 57°F (13.9°C) are the reported optimum for smoltification and emigration (DWR et al. 2000; IEP 1998).	
emigration timing range	Time of year juveniles commence emigration and duration of emigration	Central Valley winter-run steelhead emigration occurs from December through August (McEwan 2001).	
emigration timing peak	Time of year most juveniles are emigrating.	Peak catch of yearling steelhead (both hatchery and naturally produced fish) in rotary screw traps in the Sacramento River near Knights Landing from September 1997 through October 1998 occurred from week 10 through 13 (i.e., throughout March) (Snider et al. 2000). At pumping plants in the Delta, peak numbers of juvenile steelhead are observed in March and April (U.S. Fish and Wildlife Service 1995). Peak emigration of Central Valley winter-run steelhead occurs from January through May (McEwan 2001).	
size range of juveniles during emigration	Minimum and maximum sizes (inches or mm) of emigrating juveniles. Indicate average size.	Variable among YOY, smolt, and yearlings.	

Element	Element Descriptor	General	Feather River Specific
factors associated with emigration	Pulse flows, water temperature changes, turbidity levels, photoperiod, etc.		
Other potential factors			
DO	Levels of dissolved oxygen in water expressed in mg/l tolerated by fish.	In experimentally controlled conditions, fertilized steelhead eggs were subjected to a range of water velocities and dissolved oxygen levels and held at constant temperatures. Complete mortality of embryos occurred at dissolved oxygen concentrations of 1.6 mg/L, whereas 78-85% hatching success occurred at dissolved oxygen concentrations of 2.6 mg/L (the next highest treatment level). In summary, reductions in dissolved oxygen concentration, as well as decreases in water velocity each resulted in a longer developmental period to hatching, smaller embryos throughout development and at hatching, higher pre- and post-hatching mortalities, and an increased occurrence of structurally abnormal embryos (Silver et al. 1963). Based on literature review of steelhead incubation, survival of steelhead embryos increases with increasing levels of dissolved oxygen, which is indirectly related to velocity (i.e., increasing velocity typically supplies a greater concentration of dissolved oxygen; however, lower velocities are sufficient if dissolved oxygen levels remain high) (Chapman 1988). At low water temperatures, rainbow trout survive dissolved oxygen concentrations as low as 1.5–2.0 mg/L, but require a dissolved oxygen concentration close to saturation for growth (Moyle 2002).	
pH	Alkalinity/acidity of water (expressed in pH) that fish can tolerate.	Rainbow trout can live at pH values of 5.8–9.6, and the reported optimal range is 7.0–8.0 (Moyle 2002).	

Element	Element Descriptor	General	Feather River Specific
turbidity	Indicate turbidity or state of water (e.g., clear water or presence of siltation or organic/inorganic matter in water) that fish can tolerate.	Steelhead tolerate wide range of turbidities from clear low flow periods to turbid water runoff conditions.	
factors contributing to mortality	e.g. fishing/angling mortality, drastic habitat alterations, unfavorable climatic changes, etc.	Stressors affecting steelhead on the west coast include logging, agriculture, urbanization, disease, predation, water diversions, dams and other structures, gravel mining, dredging and sediment disposal, and contaminants (McEwan 2001). Although hatcheries have maintained the steelhead fishery in Sacramento River, habitat protection and restoration measures for wildstocks were largely ignored (Moyle 2002). Water development and management activities have been identified as the primary stressor to Central Valley steelhead (McEwan 2001). Hatchery strains of rainbow trout are typically of mixed origins because of intense selection for desirable traits, such as rapid growth under crowded conditions, resistance to disease, and high fecundity (Moyle 2002).	

References

Busby P.J., T. C. Wainwright, G. J. Bryant, L. J. Lierheimer, R. S. Waples, F. W. Waknitz, and Lagomarsino I.V. 1996. Status Review of West Coast Steelhead From Washington, Idaho, Oregon, and California. Report # NMFS-NWFSC-27. NOAA Tech. Memo. U.S. Dep. Commer.

California Department of Fish and Game. 2002. State and Federally Listed Endangered and Threatened Animals of California. California: The Resource Agency, Department of Fish Game, Habitat Conservation Division, Wildlife and Habitat Data Analysis Branch, California Natural Diversity Database.

CDFG. Accessed on January 17, 2003. 2002 Fresh Water Sport Fishing California Regulations. Available at http://www.dfg.ca.gov/fg_comm/02freshfishregs.pdf.

Cech, J. J. and C. A. Myrick. August, 1999. Steelhead and Chinook Salmon Bioenergetics: Temperature, Ration, and Genetic Effects. Technical Completion Report for Project Number UCAL-WRC-885.

Chapman, D. W. 1988. Critical Review of Variables Used to Define Effects of Fines in Redds of Large Salmonids. Transactions of the American Fisheries Society 117:1-21.

DWR. January 25, 2003. Presentation of Feather River Juvenile Fish Studies As They Relate to Instream Flow Studies Made by Bradley Cavallo at Oroville Facilities FERC Relicensing Fisheries Technical Input Session.

DWR and USBR. 2000. Effects of the Central Valley Project and State Water Project on Steelhead and Spring-Run Chinook Salmon. California Department of Water Resources; U.S. Bureau of Reclamation.

Hutchison, V. H. 1976. Chapter No. 5. Thermal Ecology II *in* Environmental Tolerances and Requirements of Splittail. Young, P. S. and Cech, J. J. (ed.), Springfield, Virginia: Technical Information Center, CONF-750425, 664-678.

IEP. November 1998. Monitoring, Assessment, and Research on Central Valley Steelhead: Status of Knowledge, Review of Existing Programs, and Assessment of Needs.

McEwan, D. 2001. Central Valley Steelhead *in* Contributions to the biology of Central Valley salmonids. R.L.Brown (ed.), CDFG, 1-43.

McEwan, D. and T. A. Jackson. February 1996. Steelhead Restoration and Management Plan for California. CDFG, 1-234.

Merz, J. E. 1994. A Dietary Analysis of Juvenile Sacramento Squawfish (*Ptychocheilus grandis*), Chinook Salmon (*Oncorhynchus tshawytcha*), and Steelhead Trout (*O. mykiss*) in the Lower American River, Sacramento County, California. California State University, Sacramento, 1-79.

Moyle, P. B. 2002. Salmon and Trout, Salmonidae - Rainbow Trout, (*Oncorhynchus mykiss*) *in* Inland Fishes of California. Los Angeles, California: University of California Press, 271-282.

Myrick, C. A. and J. J. Cech. 2000. Growth and Thermal Biology of Feather River Steelhead Under Constant and Cyclical Temperatures. Technical Completion Report for DWR 1-19.

NMFS. March 19, 1998. Final Rule: Notice of Determination. Endangered and Threatened Species: Threatened Status for Two ESUs of Steelhead in Washington, Oregon, and California. Federal Register 63:(53) 13347-13371.

Orcutt, D. R., B. R. Pulliam, and A. Arp. 1968. Characteristics of Steelhead Trout Redds in Idaho Streams. Transactions of the American Fisheries Society 97:42-45.

Rich, A. A. May 2000. Water Temperature Requirements for Chinook Salmon and Steelhead Trout. Testimony Submitted to the State Water Resources Control Board, Yuba River hearings, 1 May 2000 (Exhibit S-DFG-39). 12 p. *in* Contributions to the biology of Central Valley salmonids. Volume 1. R.L. Brown (ed.). Sacramento, California. CDFG, 1-297.

S.P. Cramer & Associates. 1995. The Status of Steelhead Populations in California in Regards to the Endangered Species Act. Report Submitted to the National Marine Fisheries Service on Behalf of the Association of California Water Agencies. Gresham, OP: S.P. Cramer & Associates, Inc.

Silver, S. S., C. E. Warren , and P. Doudoroff. 1963. Dissolved Oxygen Requirements of Developing Steelhead Trout and Chinook Salmon Embryos at Different Water Velocities. Transactions of the American Fisheries Society 92:327-343.

Snider, B. and R. G. Titus. July, 2000. Timing, Composition and Abundance of Juvenile Anadromous Salmonid Emigration in the Sacramento River Near Knights Landing, October 1997 - September 1998. Stream Evaluation Program Technical Report No.00-05.

U.S. Fish and Wildlife Service. 1995. Working Paper on Restoration Needs: Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California. Vol 2. Stockton, CA: Prepared for the U.S. Fish and Wildlife Service under the direction of the Anadromous Fish Restoration Program Core Group.

Wang, J. C. S. 1986. Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories. Technical Report No. 9 (FS/B10-4ATR 86-9).